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APPLICATION NUMBER: *60/550,757*

FILING DATE: *March 05, 2004*

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17157 U.S. PTO

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PROVISIONAL APPLICATION FOR PATENT
COVER SHEET

Case No. VANM280.001PRF
Date: March 5, 2004
Page 1

Commissioner for Patents
P.O. Box 1450
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ATTENTION: PROVISIONAL PATENT APPLICATION

Sir:

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR § 1.53(c).

For: **SATELLITE BASED RELATIVE POSITIONING**

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Residence Address: Rue de Liege, 72, B-4800 Verviers, Belgium

Enclosed are:

(X) Specification in 5 pages.
(X) 1 sheet(s) of drawings.
(X) A check in the amount of $160 to cover the filing fee is enclosed.
(X) A return prepaid postcard.
(X) The Commissioner is hereby authorized to charge any additional fees which may be required, now or in the future, or credit any overpayment to Account No. 11-1410.

Was this invention made by an agency of the United States Government or under a contract with an agency of the United States Government?

(X) No.

(X) Please send correspondence to:

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CERTIFICATE OF MAILING BY "EXPRESS MAIL"

Attorney Docket No.	:	VANM280.001PRF
Applicant(s)	:	Michael Rousseau
For	:	SATELLITE BASED RELATIVE POSITIONING
Agent	:	Raimond J. Salenieks
"Express Mail" Mailing Label No.	:	EL 871275977 US
Date of Deposit	:	March 5, 2004

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SATELLITE BASED RELATIVE POSITIONING

1. Positive train detection

1.1. State of the art

In existing systems, the widespread solution for train location is performing by:

- Trackside detection devices (Track circuits, axle counters) for train detection purposes.

- Trainborne Train position determination system for Fail safe train control purposes. These train position determination systems are based on trainborne sensors (wheel sensors, radars) which give relative position of the train with reference to trackside location materialised by trackside installed balise (or equivalent devices). These trackside reference points are required because of the nature of the sensors used, in order to allow for reseting the error accumulated by the train location system over time (radars) and/or distance (wheel sensors).
  In the recently emerged train satellite location systems safe positioning is obtained using Kalman filter techniques combining satellite signals with information from several expensive and delicate sensors such as accelerometers, wheel sensors, radar, gyroscope, and so forth.

This type of implementation has an important impact on the life cycle cost of a train control/command system:

- Trackside detection system have important acquisition, installation and maintenance cost, due to the quantity of equipment to be installed and their connection by cable to Interlocking system.
- Existing Trainborne solutions, based on Wheel sensors and/or radar sensors have also important acquisition, installation and maintenance costs, mainly due to their location as they are mounted below the locomotive.

Technical problem solved by inventive embodiments

The implementation of this invention has an important impact on the life cycle cost of a train/command system because reducing the amount of equipments installed below the locomotive (reduction of acquisition, installation and maintenance cost).

The invention allows a strong reduction of the trackside signaling equipments:
- trackside detection devices (like axles counters or track circuit)
- reduction of the amount of balises to be installed in the track : balises are installed only where high accuracy is required (particularly in the station).

The use of the satellite base positioning for fail safe signaling purposes in Railways application and particularly its introduction in existing solution (like European Rail Traffic Management System (ERTMS)) based on train position determination based on trainborne sensors (wheel sensors, radar).

Description of various embodiment advantages:

In existing systems, the widespread solution for train location is performed by:

- Trackside detection devices (track circuits, axle counters) for train detection purposes.
- Trainborne Train position determination system for Faile safe train control purposes. These train position determination systems are based on trainborne sensors (wheel sensors, radars) which give relative position of the train with reference to trackside location materialised by trackside installed balise or passive transducer (or equivalent devices).

1.2.Rational of the solution

The solution proposed for RBS system is to use trainborne train location system for both Train detection purposes (positive train detection) and for Fail safe train control purposes.

To reduce inconvenience and life cycle cost of existing solution quoted above, Alstom has developed a vital fail-safe positive train detection and tachometric system relying mainly on satellite navigation, without need for sensor fusion : the Satellite-based Navigation system for Train Control.

As said, this solution relies mainly on GNSS satellites, from GPS, GLONASS and future Galileo constellations, even if:
- ◆ Balises are used to increase the accuracy at dedicated locations
- ◆ Additional sensors on-board may be used if required to cover dedicated situations like long tunnels. For RBS, it is foreseen to re use existing wheel sensors for this purpose.

1.3.Pure GNSS based Train location solution

A pure GNSS based Train location solution, also called "Narrow Matching" approach, takes advantage of the deterministic trajectory of the train to reach the optimal compromise between safety, availability and accuracy with non-supplemented SatNav equipment.

Pure GNSS based Train location solution relies on:
- On-board safe digital mapping of possible trajectories;
- step-by-step determination of the relevant trajectory via a dialogue with the ROC or with the Interlocking (in the large stations);

Actually, in case of parallel tracks or junction of tracks, the accuracy of the satellite positioning alone, even considering the addition of costly sensors or augmentation system,

doesn't allow to determine in real time which track the train is moving on with the level of safety required for railways application.
In the proposed solution, the trainborne equipment determines safely on which track the train is running by monitoring the point position through a radio dialogue with the local interlocking.
As the trainborne database contains the geometrical description of the tracks used by the train, the trajectory of the train is then unambiguously known.

As a consequence, an accuracy of 1.5 to 2 meters in safety is not required.

- Fail safe hyperbolic mono dimensional (1D) positioning on the selected trajectory.

Navigation satellites transmit a coded signal of which the transmission time between satellites and the mobile to be localised can be "measured" by the train receiver and converted in length information called "pseudo range".
The receiver clock does not need tight synchronisation with the navigation satellites atomic clocks, since this is removed by calculating the difference between pseudo ranges of two different satellites of the same constellation.
In space, the possible positions of the receiver that correspond to this difference of pseudo ranges to those two satellites are contained on a revolution hyperboloid.
Calculated Pseudo range contains errors due to transmitter position error, atmospheric variation of the transmission speed, multipath, receiver noise and so forth.
The receiver "position" is given by the intersection between the selected trajectory and the calculated hyperboloid.
As the distribution of the error on the range is known, it is possible to define a confidence interval on the track where the train is.
Combining confidence intervals calculated with multiple selected pairs of satellites, it is possible to define a resulting confidence interval in which the probability for the train to be outside is extremely low and in line with the level of safety required for railway application.

2. Localization accuracy augmentation

The localisation accuracy has a direct impact on the system performances and the corresponding line throughput. The requirement on localisation accuracy to allow maximum throughput of the line is stronger in loop section that in line section of the track.
This need for higher accuracy in loop section is due to the fact that:

- the RBS trainborne equipment is fully supervising the train with reference to the end of movement authority, on the basis of the trainborne safe localisation, therefore taking into account the confidence interval related to the inaccuracy,
- The RBS trainborne equipment is able to release the resource at the back of "its" train, making this resource available to another train crossing or overpassing it in the crossing loop section, only after the safe rear position of the train has passed the fouling point of the point at its back.

This is illustrated for the ATC alternative by the figure below

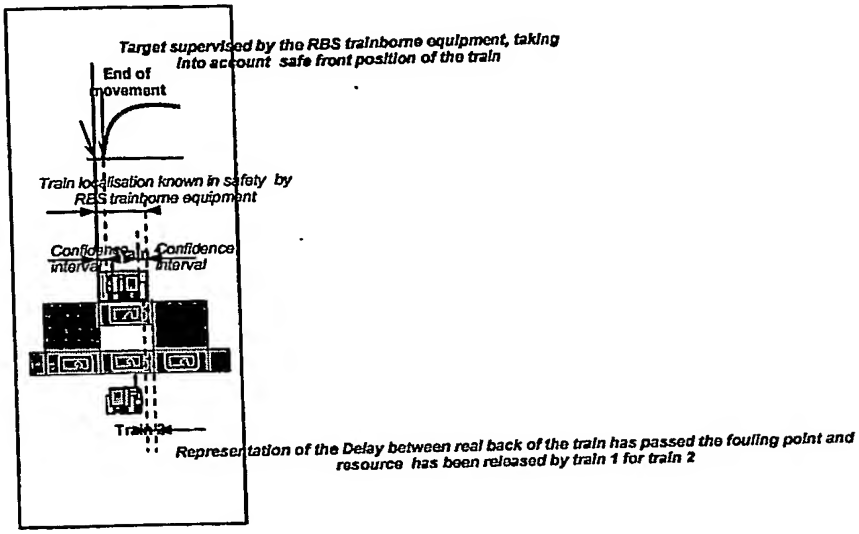

Figure 1

Considering the life cycle cost of the system proposed, the basic solution proposed for the RBS is to provide a higher accuracy by using the balise augmentation solution.

<u>Certain inventive embodiments are based on a the following principle:</u>

Each time a balise is met by the train, the trainborne location system works in a balise augmented mode, which consist in using the balise position as a reference and to compute the actual train position with reference to this balises, by integrating the actual speed of the train.

When the accuracy provided by this means is lower than the accuracy provided by pure GNSS based train location algorithm, the trainborne location system stops using the balise augmented mode information and starts to use the pure GNSS based train location information and uses this one until next balise is met.

<u>Advantages(s) of certain inventive embodiments:</u>

Reduction of the life cycle cost of a train control/command system:

- Reduction of trackside detection devices (no track circuit or axle counters)
- Reduction of amount of equipment mounted below the car
- Reduction of the amount of balise (installed only in dedicated location where high accuracy is needed: particularly the station).

ABSTRACT

SATELLITE BASED RELATIVE POSITIONING

The present innovation consists in a new positioning subsystem using both the GNSS signals and relocalisation passive balise installed in the track. The position of the train is computed with reference to the balise by integrating the actual speed of the train (calculated via the GNSS doppler signals). In addition, when the accuracy provided by this mean is lower than the accuracy provided by absolute train positioning, the subsystem stops to use the balise.

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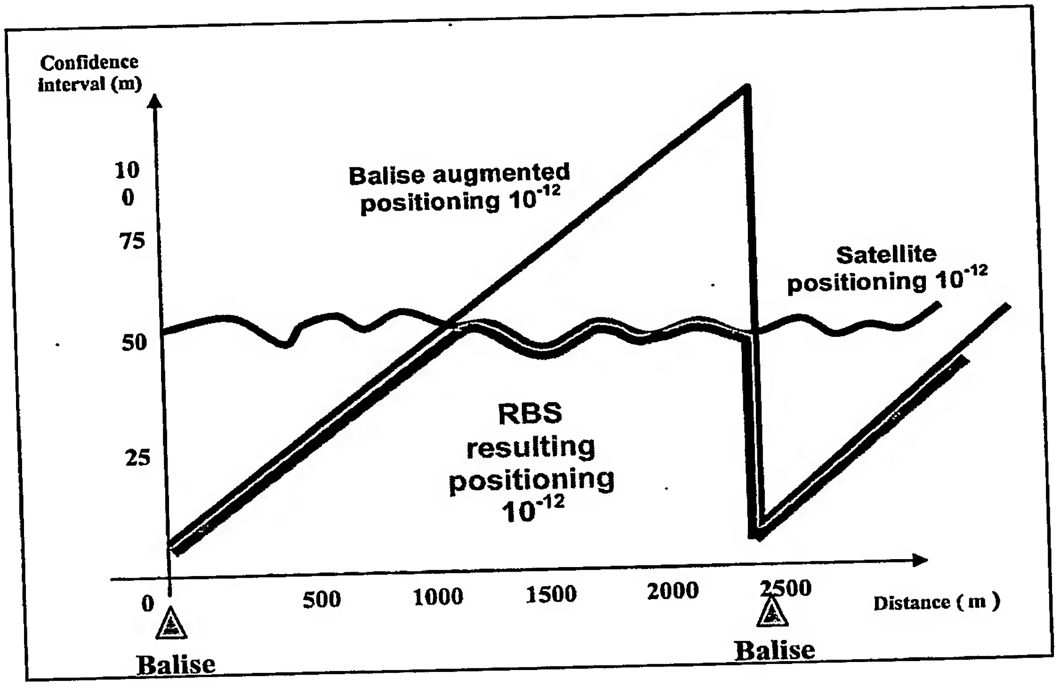
Confidence interval (m)
10
0
75
50
25
Balise augmented positioning 10^{-12}
Satellite positioning 10^{-12}
RBS resulting positioning 10^{-12}
0
500
1000
1500
2000
2500
Distance (m)
Balise
Balise

Figure 2